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Serial No. 09/938,453

**AMENDMENTS TO THE CLAIMS:**

This listing of claims will replace all prior versions, and listings, of claims in the application:

1        1. (Currently amended) A method for compensating for time dispersion in a  
2 receiver of a wireless system that has a plurality of transmit antennas and a plurality of  
3 receive antennas, the method comprising the steps of:

4            receiving samples for each receive antenna;

5            determining a joint equalizer solution using channel information for at least one  
6 pairing of at least one of said transmit antennas and said receive antennas and said  
7 received samples of at least two of said receive antennas; and

8            applying said determined joint equalizer solution to said received samples from at  
9 least one of said receive antennas to develop equalized samples;

10            wher cin said step of determining a joint equalizer solution is performed at least  
11            partly in the discrete frequency domain.

1        2. (Original) The invention as defined in claim 1 wherein said joint equalizer  
2 solution is a joint minimum mean square error (MMSE) solution.

1        3. (Currently amended) The invention as defined in claim 1 further comprising  
2 the step of estimating a channel for said at least one pairing of at least one of said transmit  
3 antennas and said receive antennas.

1        4. (canceled)

1        5. (canceled)

1        6. (canceled)

1        7. (Original) The invention as defined in claim 1 said step of applying said  
2 determined joint equalizer solution is performed in the frequency domain.

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1        8. (Currently amended) A method for compensating for time dispersion in a  
2 receiver of a wireless system that has a plurality of transmit antennas and a plurality of  
3 receive antennas, the method comprising the steps of:  
4        receiving samples for each receive antenna;  
5        determining a joint equalizer solution using channel information for at least one  
6 pairing of at least one of said transmit antennas and said receive antennas and said  
7 received samples of at least two of said receive antennas;  
8        applying said determined joint equalizer solution to said received samples from at  
9 least one of said receive antennas to develop equalized samples; and  
10      ~~The invention as defined in claim 1 further comprising the step of despreading~~  
11 ~~said equalized samples.~~

1        9. (Previously presented) The invention as defined in claim 1 wherein at least two  
2 of said transmit antennas transmit at different rates.

1        10. (Previously presented) The invention as defined in claim 1 wherein at least  
2 two of said transmit antennas transmit using different transmit constellations.

1        11. (Previously presented) The invention as defined in claim 1 further comprising  
2 the step of performing soft mapping using a version of said equalized samples.

1        12. (Original) The invention as defined in claim 11 wherein said version of said  
2 equalized samples are despread samples.

1        13. (Original) The invention as defined in claim 11 wherein said step of  
2 performing soft mapping further comprises the step of spatial whitening said version of  
3 said equalized samples.

1        14. (Original) The invention as defined in claim 11 wherein said step of  
2 performing soft mapping further comprises the step of performing a posteriori probability  
3 (APP) metric processing on said version of said equalized samples.

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1        15. (Original) The invention as defined in claim 1 wherein said determining step  
2        is performed multiple times, once for each one of said transmit antennas.

1        16. (Original) The invention as defined in claim 1 wherein said determining and  
2        applying steps are iterated multiple times over a symbol period, one iteration for each one  
3        of said transmit antennas, and said method further comprises, for each iteration, the steps  
4        of:

5            generating a representation of signals that would have arrived had a particular  
6        symbol for a currently being processed transmit antenna had been transmitted; and

7            subtracting said representation from said samples received for each receive  
8        antenna.

1        17. (Original) The invention as defined in claim 1 wherein said joint equalizer  
2        solution is one from the group consisting of: a joint least mean square (LMS) solution, a  
3        joint recursive least squares (RLS) solution, or a joint minimum intersymbol interference  
4        (ISI) subject to an anchor condition solution.

1        18. (Currently amended) A receiver for use in a multiple-input multiple-output  
2        (MIMO) system in which a plurality of signal detectors receive signals transmitted by a  
3        plurality of signal sources, said receiver comprising:

4            a joint equalizer that develops a joint equalizer solution using channel information  
5        for at least one pairing of said at least one of said signal sources and said signal detectors  
6        and received samples of at least two of said signal detectors and supplies as an output a  
7        signal that includes at least said joint equalizer solution applied to a signal received by at  
8        least one of said signal detectors; and

9            a soft bit mapper for developing soft bits from said joint equalizer output; and  
10          a despreader interposed between said joint equalizer and said soft bit mapper.

1        19. (Original) The invention as defined in claim 18 wherein said joint equalizer  
2        solution is a joint minimum mean square error (MMSE) equalizer solution

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1        20. (Original) The invention as defined in claim 18 wherein said soft bit mapper  
2 further comprises an a posteriori probability (APP) metric processor.

1        21. (Original) The invention as defined in claim 18 wherein said soft bit mapper  
2 further comprises a spatial whitening unit.

1        22. (canceled)

1        23. (Original) The invention as defined in claim 18 wherein at least two of said  
2 transmit sources transmits signals at different rates.

1        24. (Original) The invention as defined in claim 18 wherein at least two of said  
2 transmit sources transmits signals using different transmit constellations.

1        25. (Original) The invention as defined in claim 18 further comprising:  
2              a space time regenerator coupled to said joint equalizer; and  
3              a buffer-subtractor coupled between said signal detectors and said joint equalizer  
4 and between said space time regenerator and said joint equalizer.

1        26. (Original) The invention as defined in claim 25 further comprising a front end  
2 processor coupled to said buffer-subtractor.

1        27. (Currently amended) The invention as defined in claim 18 further comprising  
2              ~~a soft bit mapper coupled to said joint equalizer;~~  
3              an error correction decoder coupled to said soft bit mapper;  
4              a space time regenerator coupled to said error correction decoder; and  
5              a buffer-subtractor coupled between said signal detectors and said joint equalizer  
6 and between said space time regenerator and said joint equalizer.

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1        28. (Original) The invention as defined in claim 27 further comprising a front end  
2        processor coupled to said buffer-subtractor.

1        29. (Original) The invention as defined in claim 18 further comprising an order  
2        controller for determining an order in which signals from said signal detectors will be  
3        processed by said joint equalizer.

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1       30. (Currently amended) ~~The invention as defined in claim 19~~

2       A receiver for use in a multiple-input multiple-output (MIMO) system in which a  
3       plurality of signal detectors receive signals transmitted by a plurality of signal sources,  
4       said receiver comprising:

5       a joint equalizer that develops a joint equalizer solution using channel information  
6       for at least one pairing of said at least one of said signal sources and said signal detectors  
7       and received samples of at least two of said signal detectors and supplies as an output a  
8       signal that includes at least said equalizer solution applied to a signal received by at least  
9       one of said signal detectors; and

10      a soft bit mapper for developing soft bits from said joint equalizer output;

11      wherein said joint equalizer solution is a joint minimum mean square error  
12      (MMSE) equalizer solution and wherein said joint equalizer further comprises:

13      a first plurality of fast Fourier transform processors, each of said fast Fourier  
14      transform processors being coupled to receive a respective input corresponding to a signal  
15      received by one of said signal detectors and supplying as an output a discrete frequency  
16      domain representation thereof;

17      a plurality of channel estimation units each of which is coupled to receive a  
18      respective input corresponding to a signal received by one of said signal detectors which  
19      develops a channel estimate for each channel between each respective signal source and  
20      each respective signal detector;

21      a second plurality of fast Fourier transform processors, each of said second  
22      plurality of fast Fourier transform processors coupled to receive a respective input  
23      corresponding to a channel estimate for a respective one of said channels between said  
24      signal sources and said signal detectors and supplying as an output a discrete frequency  
25      domain representation thereof;

26      an MMSE detection per frequency bin processor coupled to receive as inputs said  
27      outputs from said first plurality of fast Fourier transform processors and from said second  
28      plurality of fast Fourier transform processors to produce a discrete frequency domain  
29      representation of an application of said joint minimum mean square error (MMSE)  
30      equalizer solution to said signals received by each of said signal detectors; and

31      a plurality of inverse fast Fourier transform processors which convert said discrete  
32      frequency domain representation of an application of said joint minimum mean square  
33      error (MMSE) equalizer solution to the time domain.

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1        31. (Currently amended) The invention as defined in claim 30 wherein M is the  
 2        number of signal sources and N is the number of signal detectors, and  
 3        wherein said MMSE detection per frequency bin processor performs the  
 4        equalization in the frequency domain by computing

$$5 \quad \mathbf{z}(\omega) = (\mathbf{H}(\omega)^H \mathbf{H}(\omega) + \sigma^2 \mathbf{I})^{-1} \mathbf{H}(\omega)^H \mathbf{r}(\omega)$$

6        where

$$7 \quad \mathbf{H}(\omega) = \begin{bmatrix} \mathbf{h}_{1,1}(\omega) & \cdots & \mathbf{h}_{1,M}(\omega) \\ \vdots & \ddots & \vdots \\ \mathbf{h}_{N,1}(\omega) & \cdots & \mathbf{h}_{N,M}(\omega) \end{bmatrix}$$

8

$$9 \quad \mathbf{r}(\omega) = \begin{bmatrix} r_1(\omega) \\ r_2(\omega) \\ \vdots \\ r_N(\omega) \end{bmatrix}$$

$$10 \quad \sigma^2 = \frac{\sigma_n^2}{\sigma_x^2}$$

11         $\sigma_n^2$  is the background noise plus interference power,

12         $\sigma_x^2$  is the sum of the power received by all said signal detectors from all of said  
 13        signal sources,

14        each  $\mathbf{r}(\omega)$  is said output of a one of said first plurality of fast Fourier transform  
 15        processors,

16        each  $\mathbf{h}(\omega)$  is said output of a one of said second plurality of fast Fourier transform  
 17        processors,

18         $\mathbf{J}$  is the identity matrix,

19         $\mathbf{X}^H$  means the Hermitian transpose of  $\mathbf{X}$ , which is the complex conjugate  
 20        transpose of the vector or matrix  $\mathbf{X}$ , and

21         $\mathbf{z}(\omega)$  is the equalized output vector in the discrete frequency domain for frequency  
 22         $\omega$ .

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1           32. (Currently amended) The invention as defined in claim 19  
2           A receiver for use in a multiple-input multiple-output (MIMO) system in which a  
3           plurality of signal detectors receive signals transmitted by a plurality of signal sources,  
4           said receiver comprising:  
5           a joint equalizer that develops a joint equalizer solution using channel information  
6           for at least one pairing of said at least one of said signal sources and said signal detectors  
7           and received samples of at least two of said signal detectors and supplies as an output a  
8           signal that includes at least said equalizer solution applied to a signal received by at least  
9           one of said signal detectors; and  
10          a soft bit mapper for developing soft bits from said joint equalizer output;  
11          wherein said joint equalizer solution is a joint minimum mean square error  
12          (MMSE) equalizer solution and wherein said joint equalizer further comprises:  
13            a plurality of channel estimation units each of which coupled to receive a  
14            respective input corresponding to a signal received by one of said signal detectors which  
15            develops a channel estimate for each channel between each respective signal source and  
16            each respective signal detector;  
17            a plurality of fast Fourier transform processors, each of said plurality of fast  
18            Fourier transform processors being coupled to receive a respective input corresponding to  
19            a channel estimate for a respective one of said channels between said signal sources and  
20            said signal detectors and supplying as an output a discrete frequency domain  
21            representation thereof;  
22            an MMSE tap weight calculator coupled to receive as inputs said outputs from  
23            said plurality of fast Fourier transform processors to produce a discrete frequency domain  
24            representation of a joint minimum mean square error (MMSE) equalizer solution to said  
25            signals received by each of said signal detectors;  
26            a plurality of inverse fast Fourier transform processors which convert said discrete  
27            frequency domain representation of a joint minimum mean square error (MMSE)  
28            equalizer solution to matrices of filter coefficients in the time domain; and  
29            a matrix finite impulse response (FIR) filter coupled to apply said matrices of  
30            filter coefficients in the time domain to said signals received by said signal detectors.

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1        33. (Previously presented) The invention as defined in claim 32 wherein M is the  
 2        number of signal sources and N is the number of signal detectors, and wherein said  
 3        MMSE equalizer solution is developed by computing:

4         $S(\omega) = (H(\omega)^H H(\omega) + \sigma^2 I)^{-1} H(\omega)^H$

5        where

6         $H(\omega) = \begin{bmatrix} h_{1,1}(\omega) & \dots & h_{1,M}(\omega) \\ \vdots & \ddots & \vdots \\ h_{N,1}(\omega) & \dots & h_{N,M}(\omega) \end{bmatrix}$

7         $\sigma^2 = \frac{\sigma_n^2}{\sigma_s^2}$

8         $\sigma_n^2$  is the background noise plus interference power,  
 9         $\sigma_s^2$  is the sum of the power received by all said signal detectors from all of said  
 10      signal sources,

11      each  $h(\omega)$  is said output of a one of said plurality of fast Fourier transform  
 12      processors,

13       $I$  is the identity matrix,

14       $X^H$  means the Hermitian transpose of  $X$ , which is the complex conjugate  
 15      transpose of the vector or matrix  $X$ , and

16       $S(\omega)$  is a frequency domain matrix representing the equalization for frequency  $\omega$ .

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1        34. (Currently amended) The invention as defined in claim 33 wherein said  
2 matrix FIR filter applies said matrices of filter coefficients in the time domain to said  
3 signals received by said signal detectors by computing

4               $y(k) = \sum_{j=0}^{F-1} S_j r(k-j)$

5  
6        where  $y(k)$  is the a vector output at time  $k$ ,  $y$  having one component for each of  
7 said signal sources,

8         $S_j$  is a  $M \times N$  filter matrix for delay  $j$ , which is the inverse Fourier transform of  
9         $S(\omega)$ ,

10         $r(k)$  is a vector of received samples at time  $k$ , and

11         $F$  is the number of samples taken for each fast Fourier transform by each of said  
12 plurality of fast Fourier transform processors.

1        35. (Original) The invention as defined in claim 18 wherein said MIMO system is  
2 a wireless system, said signal sources are transmit antennas and said detectors are  
3 antennas of said receiver.

1  
1        36. (Original) The invention as defined in claim 18 wherein said joint equalizer  
2 develops said joint equalizer solution as a function of estimates of the channels between  
3 each of said signal sources and said signal detectors.

1  
1        37. (Previously presented) The invention as defined in claim 18 wherein said  
2 joint equalizer develops and applies said joint equalizer solution in a time domain.

1  
1        38. (Previously presented) The invention as defined in claim 18 wherein said  
2 joint equalizer develops and applies said joint equalizer solution in a frequency domain.

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1        39. (Previously presented) The invention as defined in claim 19 wherein said  
 2 joint equalizer develops and applies said joint equalizer solution in a discrete frequency  
 3 domain and applies said joint minimum mean square error (MMSE) equalizer solution in  
 4 a time domain.

1        40. (Previously presented) The invention as defined in claim 19 wherein said joint  
 2 equalizer develops said joint minimum mean square error (MMSE) equalizer solution by  
 3 computing

$$4 \quad \mathbf{W} = \mathbf{A} \Gamma(\mathbf{H})^H \left( \Gamma(\mathbf{H})^H \Gamma(\mathbf{H}) + \frac{\sigma_n^2}{\sigma_x^2} \mathbf{R}_{pp} \right)^{-1}$$

5        where

6         $\Gamma(\mathbf{H})$  is a MIMO convolution operator,

7         $\mathbf{X}^H$  means the Hermitian transpose of  $\mathbf{X}$ , which is the complex conjugate  
 8 transpose of the vector or matrix  $\mathbf{X}$ ,

9         $\mathbf{A}$  is a delay matrix ,

10       $\sigma_n^2$  is the background noise plus interference power,

11       $\sigma_x^2$  is the sum of the power received by all said signal detectors from all of said  
 12 signal sources,

13      noise covariance  $\mathbf{R}_{pp}$ ,

14      and said joint equalizer applies said joint minimum mean square error (MMSE).  
 15 equalizer solution by computing

$$16 \quad \mathbf{y}(k) = \mathbf{W}\mathbf{r}(k)$$

17      where  $\mathbf{r}(k)$  is a vector of received samples at time  $k$ , and

18       $\mathbf{y}(k)$  is the vector output at time  $k$  representing the application of said joint  
 19 minimum mean square error (MMSE) equalizer to said vector of received samples at time  
 20  $k$ .

1        41. (Original) The invention as defined in claim 18 wherein said joint equalizer  
 2 solution is one from the group consisting of: a joint least mean square (LMS) solution, a  
 3 joint recursive least squares (RLS) solution, or a joint minimum intersymbol interference  
 4 (ISI) subject to an anchor condition solution.

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1        42. (Currently amended) A receiver for use in a multiple-input multiple-output  
2 (MIMO) system in which a plurality of receive antennas receive signals transmitted by a  
3 plurality of transmit antennas, said receiver comprising:

4            means for (i) developing a joint equalizer solution using channel information for  
5 at least one pairing of at least one of said transmit antennas and said receive antennas and  
6 said received samples of at least two of said receive antennas, said joint equalizer solution  
7 being developed at least partly in a frequency domain, and (ii) supplying as an output a  
8 signal that includes at least said joint equalizer solution applied to a signal received by at  
9 least one of said receive antennas; and

10            means for developing soft bits from said output signal.

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